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RUNNING HEAD: THE TRUTH ABOUT CHICKENS AND BATS

The Truth about Chickens and Bats: Ambiguity Avoidance Distinguishes Types of Polysemy.

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Abstract

Words mean different things in different contexts, a phenomenon called polysemy. We talk about *lines* of both people and poetry, and *long* distances or times. Polysemy lets a limited vocabulary capture the great variety in our experiences, while highlighting commonalities. But how? Are polysemous senses contextually-driven modifications of core meanings, or must each sense be separately memorized? We provide evidence for both accounts: Core meanings are used when senses follow a regular pattern (e.g., animal names for foodstuffs; *noisy/tasty chicken*), while separate representations are used when senses are idiosyncratically related (e.g., *sheet of/drinking glass*). Polysemy-type predicts participants' ability to avoid referential ambiguity when naming aloud pictures that are sometimes accompanied by same-name foils (e.g., both types of chicken/glass). Participants fail to avoid ambiguity for idiosyncratically-related foils, indicating separate meanings, but succeed for regularly-related foils, indicating a common core. We discuss implications for the relationship between word meanings and concepts.

149 words

The Truth about Chickens and Bats: Ambiguity Avoidance Distinguishes Types of Polysemy.

Although the concepts we use to think about the world appear to be unambiguous, the words we use to express them are clearly not. This is most obvious for homophones like *bat* or *bank*, but in fact almost every common word is subtly ambiguous, a phenomenon called polysemy. For instance, we can talk about *lines on a page, lines of people, lines of text, fishing lines, telephone lines,* and so on. Each sense of *line* means something slightly different, but they are all clearly connected by a common thread.

These linked senses provide language with vivid expressive power in a very economical fashion: A single word can have many interpretations, and even when its interpretation is fixed by context, the other senses can be alluded to. An account of polysemy is therefore necessary for explaining linguistic compositionality and creativity, the limitless possible meanings that can be generated by combining words.

In addition, as a conduit between words and concepts, polysemy can help explain how language and thought are linked. Those common threads that permit expressivity are presumably a reflection of, and may themselves influence, links between nonlinguistic concepts. By parceling multiple senses under a common term, language highlights similarities and relationships that might otherwise go unnoticed as we learn about the world. Moreover, by frequently highlighting metaphorical or analogical relationships (e.g., *long* describes both spatial extension and temporal duration; *hard* describes both physical attribute and personality trait) polysemy may provide one avenue by which metaphors influence cognition (Barsalou, 2008; Lakoff & Johnson, 1980, 1999; Landau, Meier, & Keefer, 2010; Uleman, 2005). In light of all this, it is important to understand exactly how words are linked to their underlying concepts.

For homophonous words, theorists agree that each word has multiple separate meanings (Ferreira, Slevc, & Rogers, 2005; Levelt, Roelofs, & Meyer, 1999). But the representation of polysemy is more controversial. One possibility, suggested by both psychologists and linguists, is that different senses do not need to be stored and represented at all. Instead, apparent senses are actually elaborations on an underspecified core meaning, which only lists characteristic and critical features (e.g., Caramazza & Grober, 1976; Frisson, 2009; Nunberg, 1979; Strigin, 1998). For instance, *line*'s meaning might specify a 1-dimensional spatial extension but omit mention of paper, people or text, which have to be filled in using context and world knowledge.

Consistent with these "core-meaning" approaches, polysemous and homophonous words behave differently in various experimental paradigms. Lexical decision times to words go down as the type count of polysemous senses increases, but go up as the type count of homophonous meanings increases (Rodd, Gaskell, & Marslen-Wilson, 2002). Reading times for sentences that use less-frequent senses of polysemous words (e.g., *Korea*'s war sense) are not reliably greater than for more-frequent senses (Frazier & Rayner, 1990; Frisson & Pickering, 1999), unlike the characteristic finding for homophones (Frazier & Rayner, 1990; Rayner & Frazier, 1989), suggesting that senses and meanings are processed differently.

Core meanings satisfy our intuition that senses are related. But, for any given polyseme, it has proven hard to precisely specify a core meaning that captures all the associated senses but not the unassociated senses. This difficulty has led other researchers to propose that senses have to be individually learned rather than inferred online; that is to say, polysemes and homophones have the same format (Klein & Murphy, 2001; Lehrer, 1990). In support of this, Klein and Murphy (2001, 2002) found that polysemes behave like homophones in several lexical processing tasks. For instance, reading a polysemous or homophonous word used with one sense/meaning (*liberal paper*) raises reading times for the same word using a different sense/meaning (*wrapping paper*).

Stored-meaning theories have one major difficulty: In their simplest form, they cannot account for the *productivity* of polysemy. Many senses follow predictable, generalizable patterns, a phenomenon called regular polysemy (Apresjan, 1974). For example, food produced from an animal or plant typically takes the same name (*tasty chicken*), a pattern that can be extended for novel foods (*tasty penguin*). Regular polysemy stands in contrast to instances of *irregular* polysemy, such as *line* or *paper,* which do not follow a predictable and generalizable pattern. Stored-meaning theories cannot explain productivity without introducing additional machinery to generate senses. Some theories assume that senses are generated by operations akin to morphological rules (e.g., an animal→food rule transforms chicken from its base animal meaning to a foodstuff meaning, Copestake & Briscoe, 1995; Lehrer, 1990; Murphy, 2007; Rabagliati, Marcus, & Pylkkänen, 2011) while others assume that both senses are specified in a single, complex (generative) lexical entry (Pustejovsky, 1995). By contrast, core meanings can explain both regular and irregular polysemy through the same mechanism of inference-to-the-best-explanation.

The critical question, then, is: Does polysemy reflect a mixture of stored irregular senses and generated regular senses, or are all polysemous senses generated through core meanings? Although previous experimental work has tended to elide the distinction between regular and irregular polysemy, this difference may explain the literature's divergent findings. Many experiments providing evidence for core meanings used regular polysemes as stimuli (Frazier & Rayner, 1990; Frisson & Pickering, 1999), while the experiments equating homophones with polysemes used mainly irregular polysemes (Klein & Murphy, 2001, 2002). Further evidence for distinct types of polysemy comes from Klepousniotou, Titone and Romero (2008). They repeated Klein and Murphy's (2001) priming experiment with polysemes that have either a weak, medium, or strong semantic relation between senses. Interestingly, while the weak and medium groups replicated Klein and Murphy's inhibitory priming, the highly-related senses showed no priming. This difference is compatible with two interpretations. One possibility is that highly-related polysemes use a distinct type of representation, and while Klepousniotou and colleagues did not manipulate regularity directly, examination of their stimuli indicates that a majority of their highly-related words followed a productive polysemy pattern (and these words were rare in the weak and medium conditions).

But alternatively, the difference could have arisen from other features of the stimuli. Prime phrases that should have unambiguously selected a sense were considerably more ambiguous in the highly-related condition. For instance, *sandwich lunch* vs. *afternoon lunch* was intended to distinguish the physical (plate of food) and temporal (time of day) senses, but neither is clearly ruled out. Furthermore, the adjectives disambiguating highly-related phrases were, by necessity, semantically related to both senses, potentially overriding any inhibitory priming. Thus, since the interpretation of these findings is ambiguous, there is no clear evidence for a distinction between types of polysemy.

To directly test whether irregular and regular polysemes dissociate, we moved away from comprehension measures to a new paradigm: Ambiguity avoidance in language production. Ferreira et al. (2005) show that, when asked to unambiguously identify a pictured object that has a homophonous label (e.g., a baseball bat), participants mistakenly produce temporarily ambiguous names if a homophonous foil is also depicted (e.g., saying "bat...no, baseball bat" if an animal bat foil is included). However, they immediately recognize and avoid the ambiguity if the foil is a second instance from the same category (e.g., saying "larger baseball bat"). That is to say, participants avoid ambiguities at the level of word-meaning, but not phonology. Ferreira (2007; Ferreira et al., 2005) therefore argues that speakers can detect overlap in meaning while formulating a message. But because homophones lack semantic overlap, speakers must rely on error-prone, comprehension-based detection, monitoring their speech for potential ambiguity.

If all polysemes have a single core meaning, then these results predict that participants should be able to avoid ambiguity when naming polysemes. But, if polysemy is a mixture of stored irregulars and generated regulars, then ambiguity avoidance should be more frequent for regular polysemes than irregular polysemes, because the former share a common meaning.

We therefore compared naming patterns when ambiguity was caused by depictions of homophones, irregular polysemes, regular polysemes, or two instances from the same category. Four pictures were displayed on a screen and assigned an order from 1 to 4. Participants memorized the order then named the pictures. To quantify ambiguity avoidance, we compared the proportion of ambiguous names produced in the presence or absence of a same-name foil.

Method

Participants

52 individuals with English as a first language (undergraduates or Cambridge, MA community members) participated for cash/course-credit.

Materials

Target-foil pairs were photographs depicting 6 homophones, 12 irregular polysemes, 12 regular polysemes, and 6 same category ambiguities. These were normed so that the probability of providing the intended ambiguous name (e.g., *bat*), without prenominal modification, did not significantly differ within pairs or across ambiguity types (see supplementary materials-R).

Homophonous meanings had separate entries in the *Oxford English Dictionary Online*. Irregular polysemy senses were listed under the same entry. Six irregulars did not fall under any systematic pattern of polysemy that we are aware of (*shirt/emergency button, single-edge/electric razor*), and six fell under a pattern in which a material describes a product (*sheets of/drinking glass, sea/kitchen sponge*). This pattern is common cross-linguistically but (unlike regular polysemes) the extended meaning is unpredictable (e.g., it is unclear what *a titanium* would be). Regular polysemes followed two patterns, object-food (*noisy/tasty chicken*, *stalks/kernels of corn*) and object-representation (*real/toy monkey, real/toy zebra*). Same category items were visually dissimilar category members (e.g., *luxury/rowing boat*, *small/large dog*).

Participants received 36 experimental trials (18 ambiguous, with target, foil, and two filler pictures; 18 unambiguous, replacing foil with filler), and 40 fillers in random order. Trial- and ambiguity-type were varied within subjects, using a Latin square design. Target and foil were counterbalanced between participants (i.e., half received *baseball bat* as target and *animal bat* as foil, and half the reverse). To encourage both simple and complex labels, half the filler trials had a third picture best described by a single word (*pen*), and half a complex phrase (*washing machine*).

Procedure

Pictures were displayed in a cross pattern, with position randomized. After a 2.5s preview, each picture was labeled from 1 to 4, with a 500ms pause between labels. The target picture was always in third position and the foil in fourth. Following a 1s pause the numbers disappeared and participants named each picture in order.

Participants were told that the study assessed communication, some trials would be ambiguous, and they should name the pictures aloud so that another person could reconstruct the ordering. Ten practice trials began the experiment.

Analyses

Experimental trials were transcribed and coded by a research assistant, and reliability-coded by the first author. Agreement was 97%; disagreements were resolved through discussion. Following Ferreira et al. (2005), we coded whether descriptions were *temporarily* ambiguous, based on whether the description of the target (third) picture lacked prenominal modification (e.g., *glass*, *glass for a window, glass pane*). Unambiguous descriptions used premodification (e.g., *pane of glass, window glass*) or a different word (e.g., *screens*). We describe temporarily ambiguous names as "bare names".

We analyzed how bare name production varied over trial type (control/ambiguous), ambiguity type (homophones/irregular polysemes/regular polysemes/same category), and their interaction using a mixed-effects logistic regression (with maximally-appropriate random-effects structure). We dummy-coded our predictors so that the control homophone condition served as a baseline against which we compared effects for other lexical ambiguity types.

Results

The proportion of bare names in the control trials of the homophone baseline did not differ from those in the control trials of any of the other conditions (all *z's* < 1.4, ns, see Figure 1 and Table 1). For homophones, bare name proportions did not reliably differ between ambiguous and control trials; that is, participants had difficulty avoiding ambiguity ($M_{control}$=0.56(SD=0.28), $M_{ambiguous}$=0.44(0.33), B=-0.71(Standard Error=0.44), Wald's *z=1.61, ns.*). Our regression tested whether the effect of trial-type for other ambiguities differed from this baseline. Replicating Ferreira and colleagues, participants were better able to avoid ambiguity for the same category items: The decrease in bare name production was reliably larger than for homophones ($M_{control}$=.0.55(0.32), $M_{ambiguous}$=0.15(0.23), B=-2.08(0.66), *z*=3.17, *p*<.01).

Critically, the patterns for irregular and regular polysemy diverged. The effect of trial type on irregular polysemes was not reliably different from the effect on homophones ($M_{control}$=0.60(0.22), $M_{ambiguous}$=0.44(0.22), B=-0.16(0.51), *z*=-0.32, *ns*). But regular polysemes patterned like unambiguous words, showing a reliably larger difference between control and ambiguous trials ($M_{control}$=0.66(0.23), $M_{ambiguous}$=0.28(0.21), B=-1.76(0.56), *z*=-3.16, *p*<.01). Importantly, a direct comparison showed greater ambiguity avoidance for regular polysemes than irregulars (B=-1.64(0.47), *z*=3.5, *p* <.001; see supplement). These results support a distinction between the representations used in regular and irregular polysemy, and are inconsistent with theories in which all senses are inferred from core meanings. (An additional analysis shows unchanged results when counting fluent phrases [*glass pane*] as unambiguous. Additional experiments have replicated these results with longer and shorter preview times. See supplement.)

We then tested alternative explanations for the irregular/regular distinction. Perhaps the pattern-like nature of regular polysemy allowed participants to predict potentially ambiguous picture-pairs? If so, ambiguity avoidance should increase over the course of the experiment for regular polysemes. A further dummy variable was added to the original regression indicating which half of the experiment each trial occurred in, along with its full set of interactions. However, ambiguity avoidance for regular polysemes did not vary across the experiment (B=-0.37(0.70), *z*=0.53, *ns*).

Next, we tested a similarity-based explanation. We contrasted two models, one in which our effects were solely due to differences in similarity, and one in which they could additionally be caused by differences in lexical representation. We collected similarity ratings for the picture-pairs (asking how much the objects had in common, on a 1-7 scale) from Amazon Mechanical Turk (n=24-30 per pair; see supplement).

We then evaluated whether a model containing predictors for trial type, similarity (centered and standardized), and their interaction explained as much variance as a more complex model including additional predictors for ambiguity type and the interaction of ambiguity type and trial type (we did not include a three-way interaction, which would have modeled differential similarity effects on ambiguity-avoidance for each ambiguity type). In fact, even accounting for additional complexity, the larger model explained significantly more variance ($\chi^2(6)=22.9$, $p<.001$). Similarity may play some role in this task, but it did not fully explain the distinction between irregular and regular polysemes.

Discussion

Polysemy lets a limited vocabulary capture the great variety in our experiences, while highlighting commonalities. Our participants' failure to notice and preempt referential ambiguity for irregular polysemes, and their relative success with regular polysemes, suggest that this mapping between ambiguous words and unambiguous concepts is achieved in two ways: Storage of individual senses (irregulars) and constrained inference over core meanings (regulars).

This dichotomy has implications for broader theories of language and language development. Accounts of how words are semantically composed into sentences (both in comprehension and production) will require mechanisms for combining both core meanings and individual senses. Developmental accounts of the lexicon need to explain how children learn individual senses while also constructing core meanings.

More broadly, our data constrain accounts of how metaphorical relationships in the lexicon (*weighty idea*, *cold personality*) might influence cognition, by showing that the common threads linking senses do not always pass through core meanings. But they leave open exactly what sort of conceptual structures contribute to the economical yet vivid expressive capacity of polysemy.

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Table 1 - Unstandardized coefficients from a mixed-effects logistic regression analysis of ambiguous name production. Predictors were dummy coded, with the unambiguous control homophone condition as baseline, so reported predictors show differences from that baseline.

Predictor	Coefficient	Wald's Z statistic
Intercept (Control Homophone condition)	0.38 (0.44)	0.86
Effect for Irregular Polysemes (coded 1, homophones = 0)	0.19 (0.53)	0.37
Effect for Regular Polysemes (coded 1, homophones = 0)	0.72 (0.53)	1.36
Effect for Same Category (coded 1, homophones = 0)	-0.11 (0.61)	0.19
Effect of Ambiguity (on Homophones, 1 = ambiguous, 0 = unambiguous control)	-0.71 (0.44)	1.61
Additional Effect of Ambiguity on Irregular Polysemes (coded 1, homophones = 0) .	-0.16 (0.51)	0.32
Additional Effect of Ambiguity on Regular Polysemes (coded 1, homophones = 0).	-1.76 (0.56)	3.16**
Additional Effect of Ambiguity on Same Category (coded 1, homophones = 0)	-2.08 (0.66)	3.17**

Note: Standard errors in parentheses. **p<.01

Figure 1 - Proportion of unmodified names by trial type and by ambiguity type. Bars indicate standard error of the mean.